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Control of Subsurface Contaminant Migration by Vertical Engineered Barriers

This Fact Sheet provides a synopsis on the use of vertical engineered barriers (VEBs) to control the migration of contamination in the subsurface. This Fact Sheet is intended to provide remedial project managers (RPMs), on-scene coordinators (OSCs), contractors, and other remediation stakeholders with a basic overview of hazardous waste containment systems constructed to prevent or limit the migration of contamination in ground water as well as their limitations.

Physical containment systems are constructed to isolate contaminated soil, ground water and aquifer materials by creating engineered barriers to ground water flow and recharge. By isolating the source(s), such systems can prevent or reduce the degradation of ground water and potential threats to human health and the environment outside the contained area. Conceptually, a containment system can be visualized as a box, whose sides, top and bottom are represented by VEBs, a cap, and an underlying low permeability unit or aquitard, respectively. Containment systems also typically include a ground water extraction system and a monitoring system (Figure 1).[1,2]

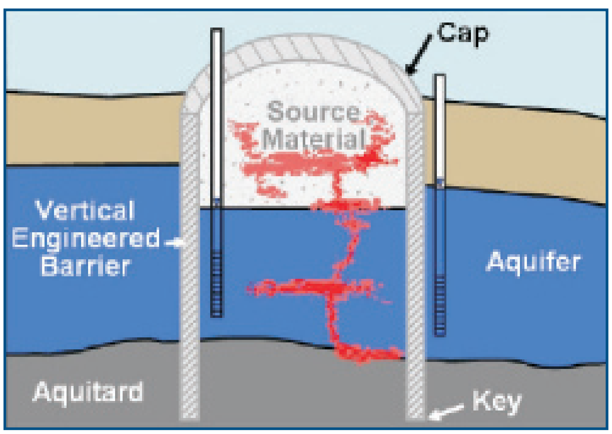

Figure 1. Major conceptual components of a containment system "box" include the cap (top), vertical engineered barrier (walls), aquitard (bottom), and monitoring wells.

- **Vertical engineered barriers** (VEBs), or cut-off walls, are most commonly slurry walls composed of native soils enriched with bentonite or another type of clay. Other materials such as cement, geomembranes, and steel sheet piling can also be used separately or in combination. Testing will generally be required to ensure that the VEB materials of construction are compatible with the wastes to be contained.[1,3,4,5,6,7]
- A **low permeability cap** is normally constructed to prohibit or reduce infiltration into the containment system. The cap may be constructed of various layers of natural and/or geosynthetic materials. If consistent with future land use, concrete or asphalt may also be used.[1,2,8]
- The **bottom** or **'floor'** of a containment system is typically a low hydraulic conductivity (K) unit, into which the wall is constructed or 'keyed'.[9] The presence of a lower confining unit and an adequate key significantly reduce the horizontal and vertical advective flow of contaminants from a containment system.[10,11] Technologies for the emplacement of low K 'floors' *in situ* have been demonstrated for relatively shallow contaminant sources.[12] Hanging wall containment systems lacking 'floors' have been used to prevent the lateral movement of light nonaqueous phase hydrocarbons.[1]
- A **ground water extraction system** is typically required to maintain inward and upward hydraulic gradients, so that the flux of water through the walls or floor is into the containment facility rather than out of it. Vertical extraction wells or horizontal drain systems can be used to remove fluids at a rate sufficient to maintain the desired inward hydraulic gradients. The extracted ground water will generally be contaminated and will require treatment.[1]
- A **good monitoring system** will incorporate a variety of monitoring techniques, rather than relying on a single method.[13] A monitoring system may include piezometers inside and outside the VEB to demonstrate that inward gradients are maintained, and in the underlying aquifer beneath the 'floor' to demonstrate an upward gradient. Ground water quality monitoring surrounding the facility may be used to demonstrate that contaminants are not leaving the system at unacceptable rates.[14,15] Monitoring will generally be needed for as long as contaminants within the containment system are potentially able to cause unacceptable exposures outside of the system.[16]

While the concept of a containment system is relatively simple, successful implementation may be difficult.[17] Available information on the performance of VEBs for hazardous waste containment suggests that the primary short term factor affecting their performance is poor construction.[10,16,18] Successful construction of a wall that meets design specification for K (typically 10^{-8} to 10^{-9} meters/second[1,10,14]) requires deployment of an experienced construction crew,[18,19,20] strict adherence to construction quality control/construction quality assurance (CQC/CQA),[1,14,16,18] and the selection of appropriate construction materials for the contaminants of concern and hydrogeologic setting.[10,21] Construction difficulties could create "windows" of higher hydraulic conductivity in some places in the wall, allowing for an outward advective flux of contaminants, or requiring a greater ground water extraction rate to maintain an inward gradient.[5,16,22] "Windows" of higher permeability or discontinuities can also occur naturally in the underlying aquitard.[9,23] Figure 2 illustrates some of the problems that can occur when containment systems are improperly designed, constructed, and/or operated. The higher water level inside the containment system relative to the upper and lower aquifers may result in leakage out of the system.

Even when a containment system is designed, constructed, and operated to design specifications, diffusive flux of dissolved volatile organic compounds (VOCs) through slurry walls, geomembranes, and the containment system floor can still occur.[24,25,26,27,28,29,30] Site specific ground water flow conditions will determine whether this steady state flux rate will result in ground water concentrations exceeding ground water cleanup criteria.

Site conditions may have an adverse impact on construction and performance of containment systems. It is not uncommon for some contamination to remain outside the perimeter of a VEB, and this can cause confusion about the integrity of the system.[1] At many sites, it may be difficult to determine the continuity and integrity of the underlying aquitard in the containment area.[9,23] Fractures in the aquitard that are hydraulically active are difficult to characterize and may allow short-circuiting of contaminants out of the containment system and into a lower aquifer.[31]

Monitoring and maintenance of the containment system are crucial to ensure that the system remains effective for as long as contamination poses a risk to areas beyond the containment system.[16] The rate at which the effectiveness of a containment system will diminish over time depends on the conservativeness of the original design, the effectiveness of the CQC/CQA program, and the adequacy of system maintenance. Currently there is insufficient data documenting the long-term performance of containment systems to predict their useful life with any degree of reliability.[15,22,32] Wells, pumps, the treatment system and its related infrastructure, and the cap will all require regular maintenance. Due to the long term (decades or centuries) nature of most of the containment systems, it is likely that some or all of the components will require repair and/or replacement during the lifetime of the system.[1,16,33]

The presence of non-aqueous phase liquids (NAPLs) in containment systems creates additional concerns. Many NAPLs may impact the integrity of the wall. For example, some NAPLs may cause shrinkage of bentonite slurry walls that may increase the K of the wall.[5,18,34] Dense NAPLs (DNAPLs) may accumulate behind a wall and eventually penetrate the lower confining unit and contaminate a deeper aquifer. Fractures in the aquitard may allow rapid downward migration of DNAPLs.[23,35,36] High dissolved phase concentrations adjacent to the wall caused by the proximity of NAPLs may allow diffusive transport of contaminants from the containment system at rates that cause unacceptable groundwater concentrations outside of the system.[30]

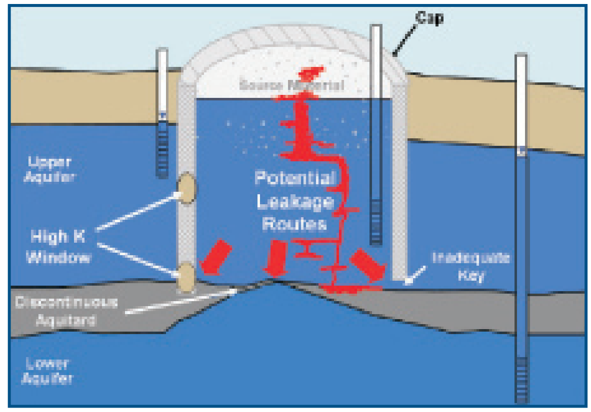

Figure 2. *Potential leakage pathways and causes for contaminants to leak out of a containment system include high K windows, discontinuities in the aquitard and inadequate keying of wall into aquitard, and higher hydraulic heads inside then out.*

Making the determination whether or not a containment system has significant leakage can be accomplished using hydraulic head data and is relatively straight forward at some sites.[37] For example, significant temporal changes in water levels indicate that water is either entering or exiting the containment system. The installation of transducer-type water level recorders inside and outside the wall may be helpful in understanding the water balance of the system.[1,16,37] However, determining the magnitude and specific location(s) of leakage will generally not be feasible with the monitoring well networks commonly found at most sites. If leakage from a containment system is deemed significant or unacceptable, additional site characterization will likely be required to determine the specific locations of leakage.[1,3,15,33,37,38] Tracers added to the contained waste may be helpful in determining the location of leakage.

At some sites, containment systems can be implemented relatively quickly to reduce the spread of contamination in the subsurface. However, the long term performance of containment systems has not been verified. Frequent maintenance and monitoring is required to maintain the desired level of effectiveness of the system. [1,3,15,16,33,37,38] Source remediation may be required within the containment system to improve the system's effectiveness.

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See Also: http://www.epa.gov/nrmrl/gwerd/

References are available at: http://www.epa.gov/nrmrl/pubs/600f10017/600f10017ref.pdf